



Quarterly Program Review

October 23, 2001

Golden, CO

***Distributed Utility Integration Test
DUIT***

DUA

Endecon Engineering

PG&E

Exelon (PECO)

CEC

Salt River Project

Encorp

Caterpillar

Solar Turbines

Onsite Energy

SMUD

Niagara Mohawk

Distributed Utility Integration Test

- 1) Build a team
 - 2) Document appropriate technologies
 - 3) Document features of appropriate site(s)
 - 4) Develop a project plan
 - 5) Develop project plan for DUIT facility at Nevada Test Site
 - 6) Design testing skid(s) and Recruitment of Industry partners for testing at NTS
- ∩ One year contract - Completion scheduled Fall, 2001
 - ∩ NREL Technical Monitor: Ben Kroposki
 - ∩ DUIT team leaders: Joe Iannucci, Susan Horgan, Chuck Whitaker, Bill Erdman

Deliverables Task 1-6

Deliverable Description

Due

Concept Paper on DUIT (Task 1)

Complete

Site Assessment Report (Task 2)

Complete

Technology Selection Report (Task 3)

Complete

Detailed Project Plan for DUIT (Task 4)

11/25/01

Detailed Project Plan for NTS (Task 5)

11/30/01

Mobile Skid (Task 6)

Fall, 2001

Design Mobile Skid

∞ Design delivery package

- DG unit
- Interconnection
- Interface equipment
- Electrical quick-connection apparatus
- Integrated fuel storage
- Industry partners to participate in characterization and field testing of DG

Task 4: DUIT Project Plan

DUIT Plan:

- ∩ **Technology plans**
- ∩ **Site specification**
- ∩ **Test plan**
- ∩ **DAS requirements**
- ∩ **Costs and schedule**

Test Plan: Issues for All Tests

- Ω High vs Low DR penetration levels
- Ω Legacy vs future distribution systems
- Ω DR a nuisance vs DR as a resource
- Ω Export vs non-export
- Ω Interaction between different distributed resources
- Ω Distributed resource types
 - Rotating: synchronous and induction
 - Inverter-based
- Ω Control aggregation
- Ω Scalability

- Ω Single vs 3 phase
 - DR, faults other events
- Ω Abnormal conditions

Testing Plan

- Ω **Anti Islanding**
- Ω **Voltage Regulation**
- Ω **Sectionalizing Devices**
- Ω **Reclosing**
- Ω **Synchronization**
- Ω **Short Circuit Current**
- Ω **Stability**
- Ω **Fuses Coordination**

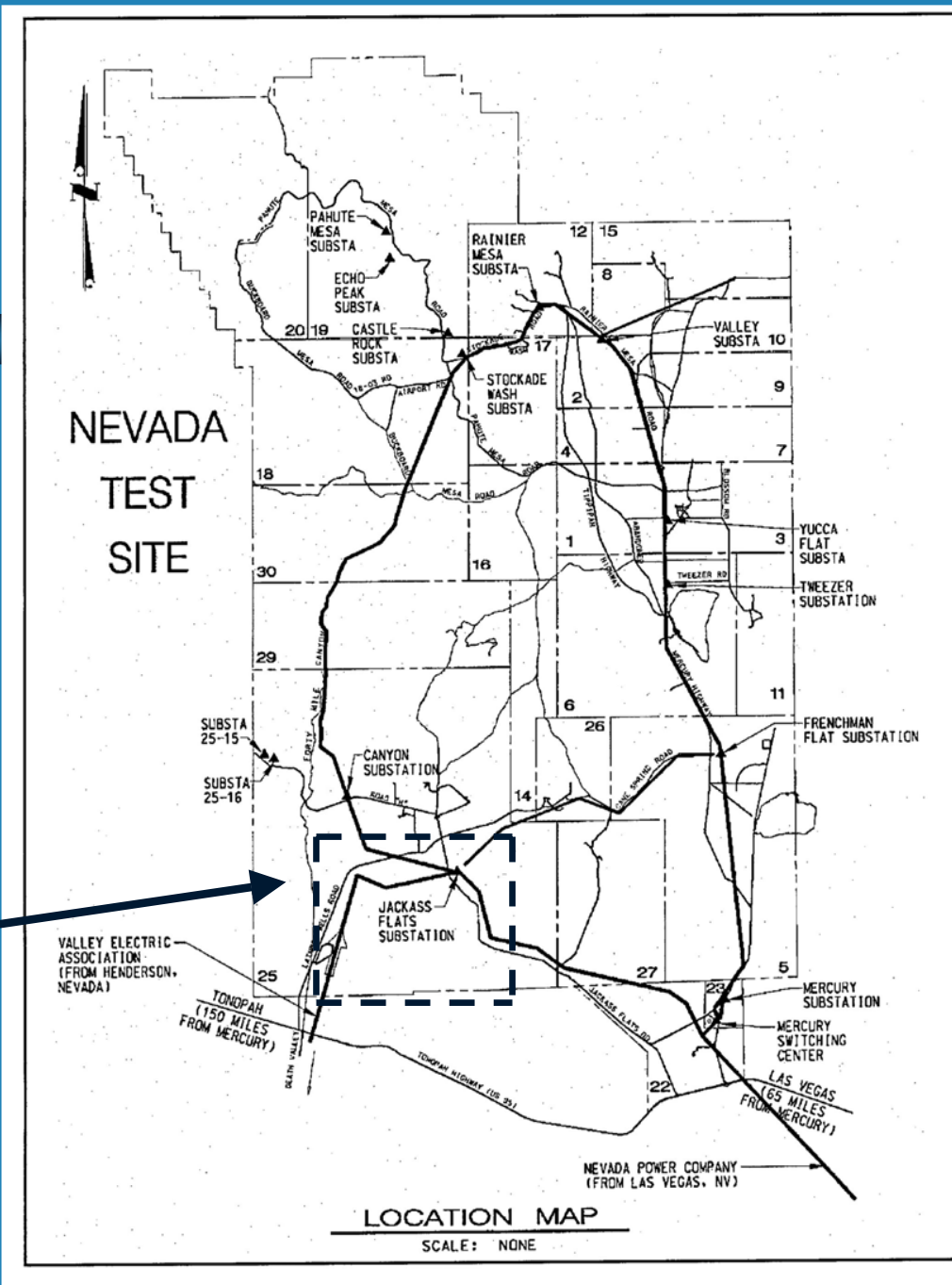
Test Plan Development

- o **Reviewed numerous documents related to DR:**
 - **IEEE 1547, IEEE 929, UL 1741**
 - **EEL DR Task Force Interconnection Study (29 Issues)**
 - **California, New York, Texas, and other existing interconnection rules**
- o **Discussed issues within the DUIT team and with many other utility engineers and equipment providers**
- o **Developed a series of test protocols**

Task 5: NTS

Distributed Power Test and Demonstration Plan

Area 25



NTS Area 25

- Ω **The site was identified as a potential test facility with existing assets:**
 - **Unused, minimally restricted 2.5 MVA substation and overhead distribution line**
 - **Local connected building load**
 - **Indoor facilities for office, communication and data acquisition**
 - **Large inventory of miscellaneous DG hardware including Diesel gensets, load banks, distribution level switchgear**
- Ω **After reviewing test plan requirements, it was decided that the test site could be used to support ambitious distribution system testing**
- Ω **Comprehensive test facility, flexible, distribution voltage and real world feeder test facility**

DUIT Test Facility - Attributes

- ⌚ **Co-location of distributed resources and loads**
- ⌚ **Real world distribution system field with 30 miles of feeder**
- ⌚ **Distribution field can be configured as a network system**
- ⌚ **Makes use of NTS material and personnel**
- ⌚ **Flexible DAS for monitoring DR and loads**
- ⌚ **Conducive to annual upgrades and project phasing**

Two Fundamental Considerations that Drive the Facility Design

Testing at distribution voltages vs. low voltages

Clearly some tests can adequately be performed at low voltage – but some cannot

Nagging question – how do low voltage results transfer to distribution voltages?

Real World (distributed parameter) feeder - lumped parameter approximation of short, medium, and long feeder

Lumped parameter feeder cost s approximately the same as real world feeder with less flexibility

Nagging question – how do results transfer to a “real “ distribution system?

Conclusion: The proposed real world feeder and voltage levels eliminate the nagging questions and add certainty in the test results



Test Protocols

Test Protocols - Review

- Ω **Test Protocol document was sent to key utilities, manufacturers and other stakeholders for review. Asked reviewers to:**
 - **Provide feedback on content**
 - **Identify missing tests or issues**
 - **Prioritize tests**
- Ω **15 respondents**
- Ω **Received several ideas for test variations**
- Ω **Prioritization was inconsistent**
 - **Several utility engineers thought Islanding tests were key while another wondered why we wasted so much ink on Islanding**
 - **Two issues seem to be of universal concern:**
 - **Islanding**
 - **Voltage Regulation**

Basic Islanding Test

⌚ **Basic Islanding Test**

- **IEEE 1547/929; UL1741**
- **Single DR with a passive RLC load**
- **No motor or non-linear loads**

⌚ **Motors represent ~60% of the electrical load**

⌚ **Motors provide inertia, ability to generate, reactance**

⌚ **Utilities have expressed considerable concern about this “deficiency”**

Islanding w/ Motor Load Test

Ω **Test Objectives:**

- **To demonstrate performance of anti-islanding schemes, a series of anti-islanding tests will be performed that include rotating loads**
- **Tests performed at a series of real power levels and mechanical inertias connected to the rotating machine**
- **Induction and synchronous machine loads, individually and collectively**

Ω **Key Testing Parameters:**

- **Real and reactive power**
- **Mechanical inertial load**

Ω **Expected Results:**

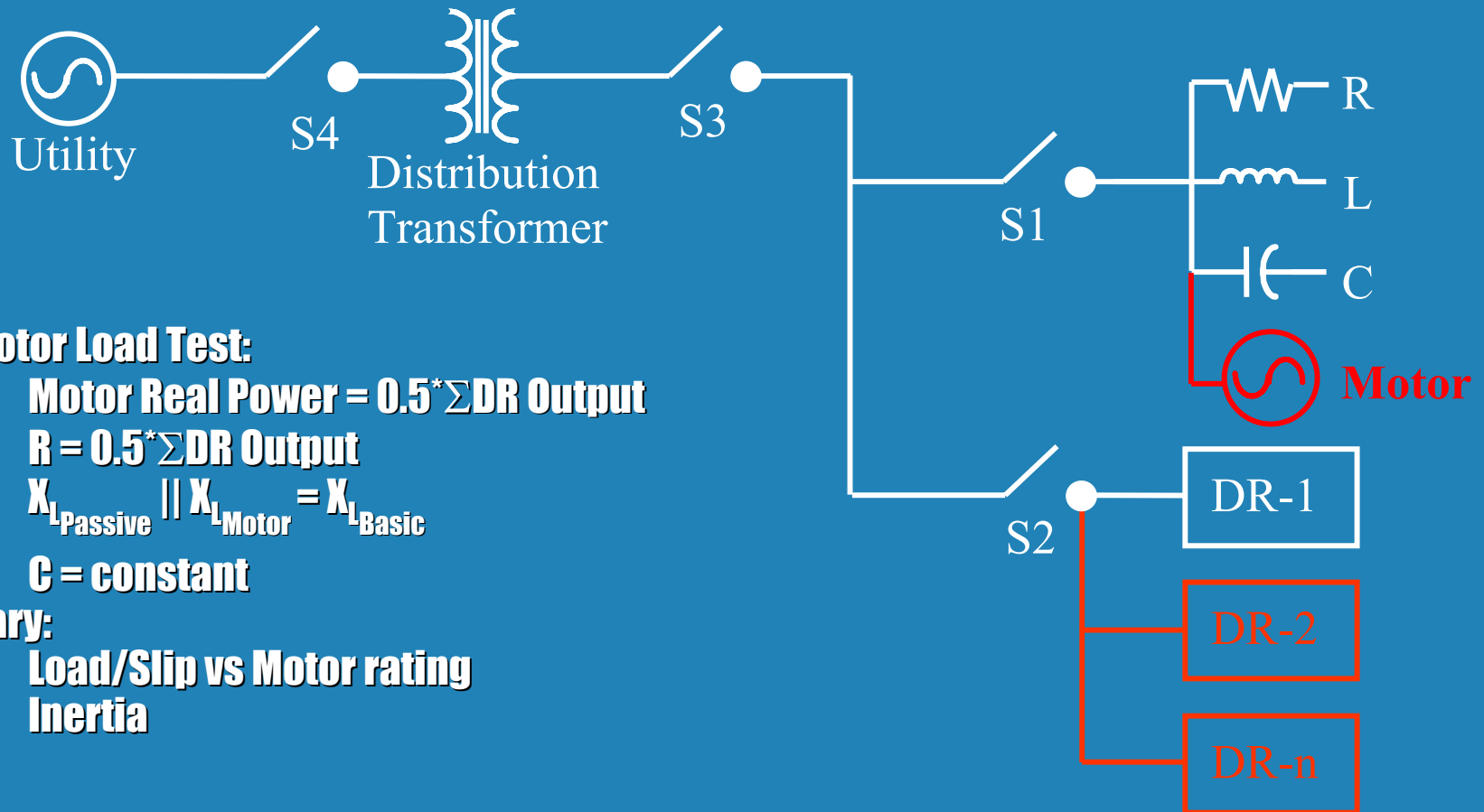
- **Quantify the effect of RLC+rotating load on trip times for DR with active anti-islanding**

Islanding Test Schematic

$$Q = \text{Load Quality Factor}$$

$$= (1/P) \sqrt{P_{ql} \times P_{qc}}$$

$$= 2.5 (\infty \text{ PF} = 0.37)$$



Motor Load Test:

- ✓ **Motor Real Power = 0.5*ΣDR Output**
- ✓ **R = 0.5*ΣDR Output**
- ✓ **$X_{L_{Passive}} \parallel X_{L_{Motor}} = X_{L_{Basic}}$**
- ✓ **C = constant**

Vary:

- ✓ **Load/Slip vs Motor rating**
- ✓ **Inertia**

Islanding Test with Motor Load: DR Requirements

- ⌚ **Repeat test with a variety of DR using a common islanding detection technique and with DR using differing islanding detection techniques**
- ⌚ **Tests should be done with combinations of single- and three-phase DR**

Type	Qty	Size	Other
Inverter, any prime mover	≥ 3	2-400 kW	Should have advanced anti-islanding function
Synchronous Generator	≥ 1	50 – 5mW	Advanced anti-islanding is desirable
Induction Generator	≥ 1	50 -500 kW	Advanced anti-islanding is desirable

Islanding Test with Motor Load: Data Acquisition Requirements

Parameter	Units	Range	Accuracy	Sampling Rate	Recording Rate
Island Contactor Status (i.e. Aux contact closure)	DC Volts	0-10Vdc	5%	600 Hz	600 Hz
Island Contactor Utility-Side Voltage	AC Volts	0-480	1%	600 Hz	600 Hz
Island Contactor Island-Side Voltage	AC Volts	0-480	1%	600 Hz	600 Hz
DR Output Current (1 per DR)	AC Amps	0-FS	1%	600 Hz	600 Hz
DR Output Voltage, DR side of DR contactor, if accessible	AC Volts	0-480	1%	600 Hz	600 Hz

DUIT Data Acquisition System Criteria

Ω Three Phase Measurement Points

- **Up to 12 Medium Voltage and 32 Low Voltage**
- **Spatially distributed over as much as 500 feet**
- **Minimum 10 samples per cycle for islanding tests**
- **Up to 50th harmonic needed for special tests**

Ω Automated load control function required

- **Repetitious Test Sequencing**

Ω Electronic data record keeping

- **Test configuration data and sampled data must be recorded in an integrated electronic data format**
- **Minimize use of paper recordkeeping**

DUIT Data Acquisition System Issues

- Ω **Data rate impact: bandwidth limits from sampling to storage**
- Ω **Simultaneous sampling**
 - **Easy to correlate events**
 - **Expensive hardware to implement**
- Ω **Signal Bandwidth Impact: CTs/PTs not spec'd for 50th harmonic**
- Ω **Data volume impacts**
 - **Working disk space**
 - **Backup/archive media and maintenance**
- Ω **Operating Temperature**
 - **Desert Location: 60C max ambient**
 - **Industrial components: 50C operating, 70C non-operating**


Data Acquisition System Options

Ω **Commercial PQ system**

- **Report-by-exception (concern that not all required data will be recorded)**
- **Less expensive hardware**
- **Requires significant effort to integrate data records**

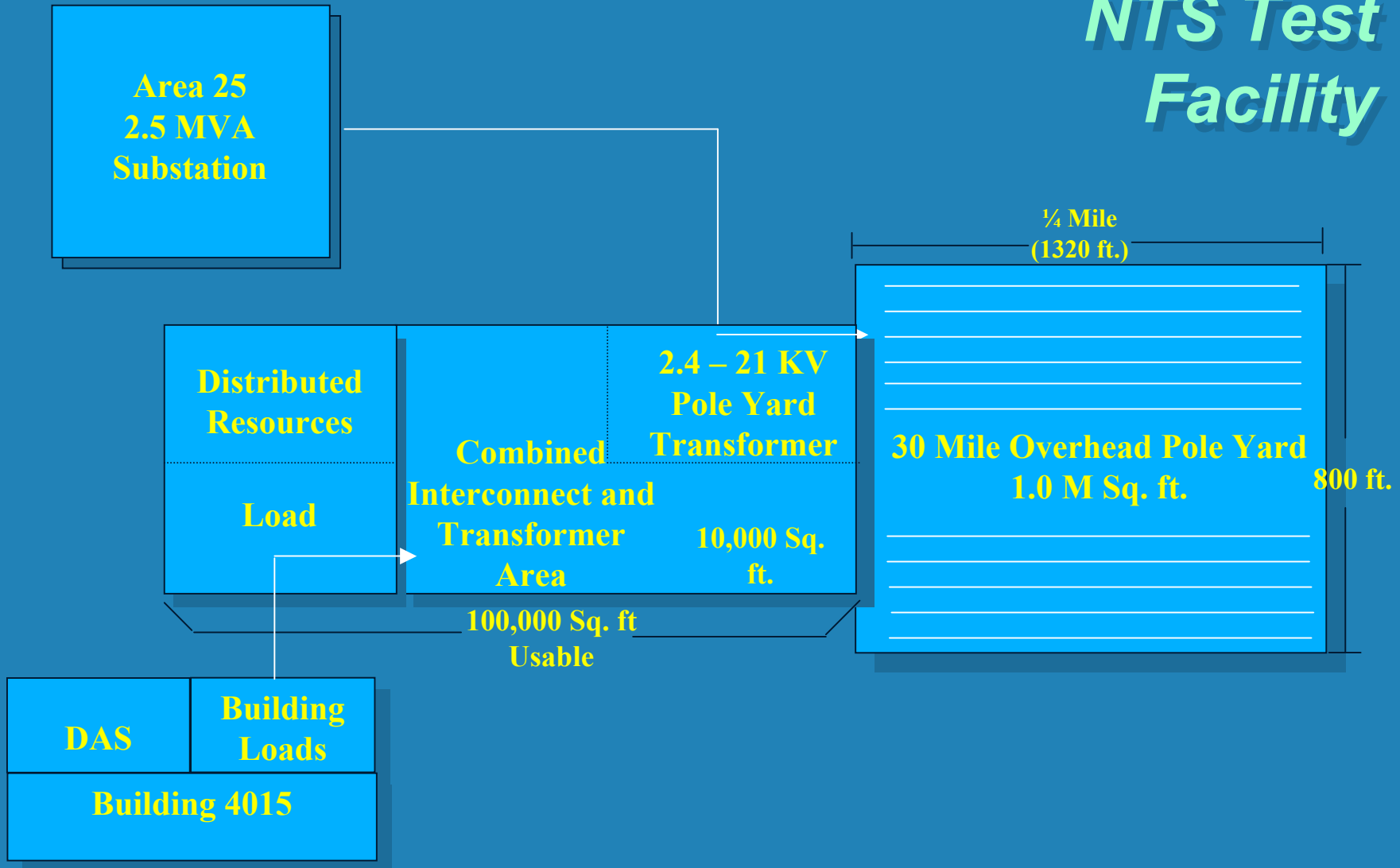
Ω **Commercial Test and Automation system**

- **Complete control of sampling parameters**
- **More expensive hardware**
 - **Larger data storage and longer post-processing times**
 - **Less integration means more individual components**

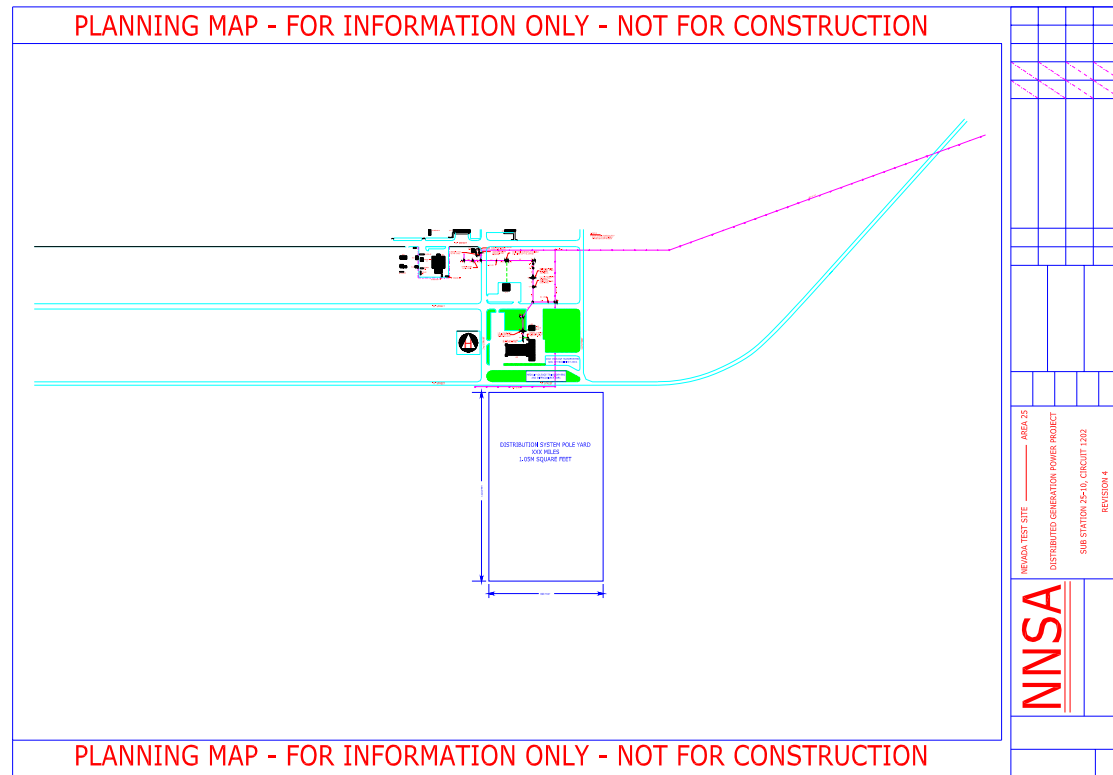


Nevada Test Site Test Facility

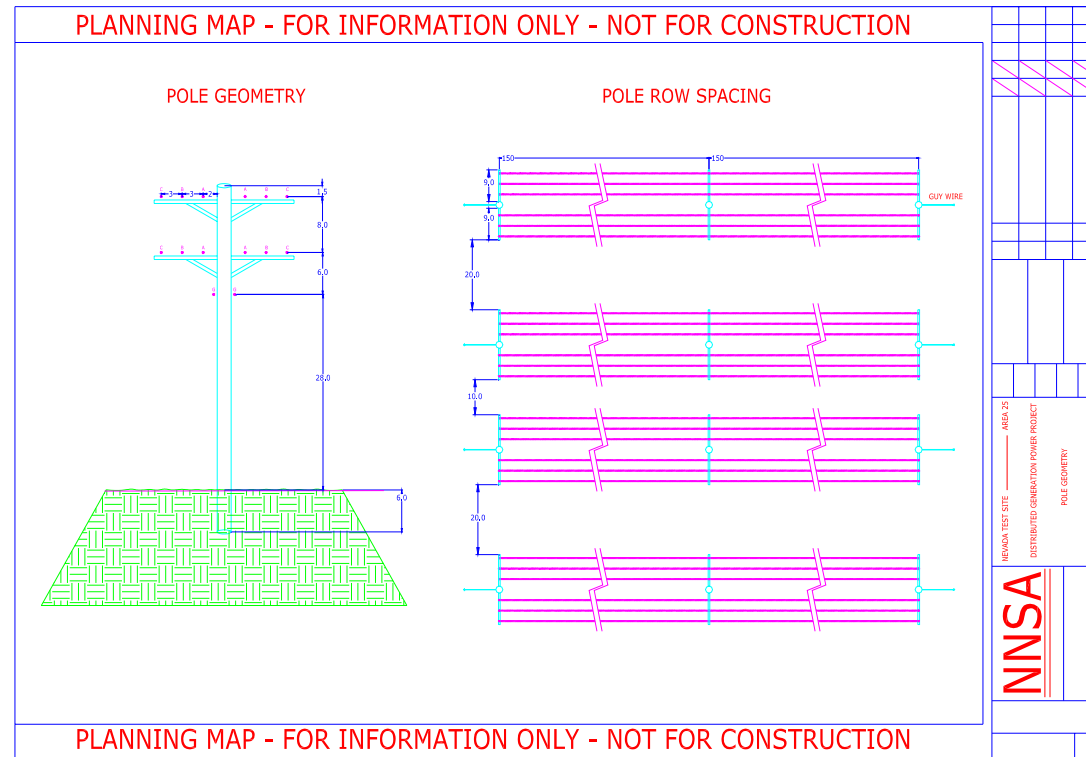
Elements of a NTS Test Facility



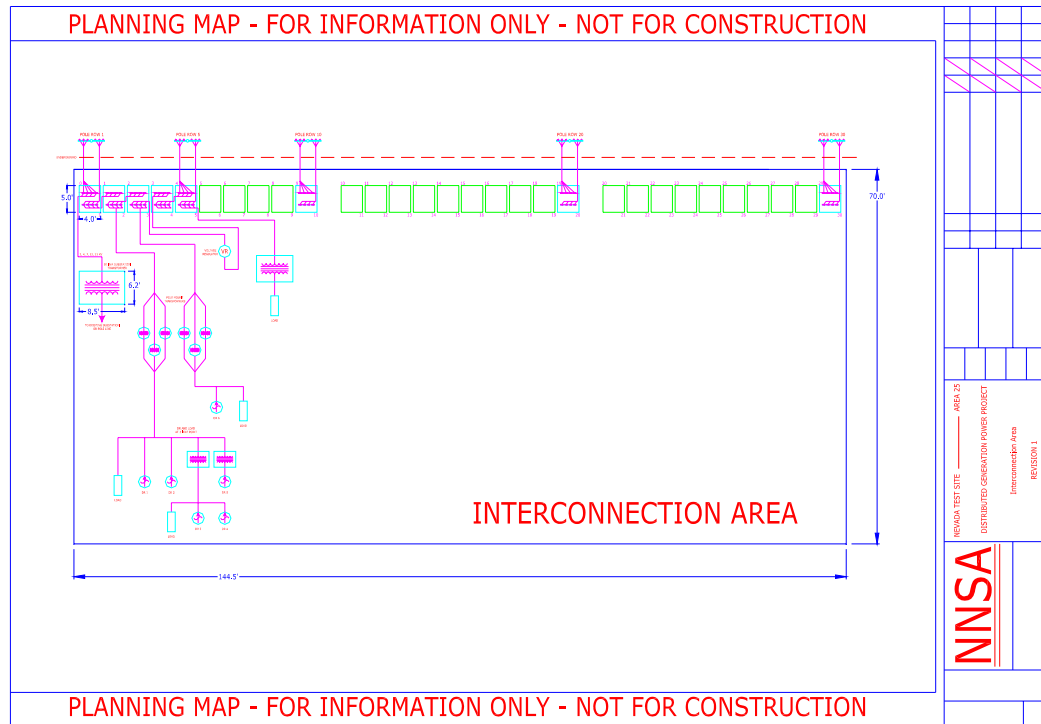
Recommended Site for Construction



Overhead Line Pole and Yard Geometries



Interconnect Area



NTS Bill of Material Summary

Feeder Yard and Interconnect Area

Item	Quantity	Description
1	280	45 ft., class 4 pole
2	1120	9 ft cross/alley arm
3	90 miles	397 MCM AAC conductor
4	15 miles	Ground conductor
5	2592	Post insulator /clamp
6	140	Ground Insulator
7	64	Dead end guy wire
8	768	Dead end insulator
9	128	End pole crossarm

Item	Quantity	Description
10	64	Turnaround crossarm
11	8	NEMA 3R termination
12	2 miles	Underground conductor
13		
14		
15		
16		
17		
18		

NTS Facility Cost Estimates

Overhead Pole Yard Materials and Construction⁽¹⁾	\$1,115,000
Interconnect Area Materials⁽²⁾	\$ 132,560
High Speed Data Acquisition System Infrastructure⁽³⁾	<u>\$ 800,000</u>
Total	\$2,047,560

Pricing Sources

- (1) Standard Utility Pricing based on two California utility data bases.**
- (2) Switchgear quotation from 2 Suppliers, surface preparation and underground cable installation excluded.**
- (3) National Instrument Based System**